ELECTRICAL INVESTIGATION OF NEURO-MUSCULAR FUNCTION -

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A. P. CAWADIAS, O.B.E., M.D., F.R.C.P.
Physician to the St. John Clinic and
Institute of Physical Medicine.

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One important application of physical medicine consists in the treatment of nervous disturbances, of disturbances of the peripheral nerves, and particularly of paralytic conditions of muscles, through electrical current -- interrupted galvanic and faradic. Galvanization and faradization are, of course, not the only methods of treatment of such conditions. Other measures, such as massage, graded exercises, general procedures of, say, ultra-violet irradiation and aerotherapy and procedures acting on muscle nutrition such as diathermy must be combined. Bit without doubt the galvanic and faradic currents are among the most valuable agents -- if not the most valuable -- in the treatment of these conditions.

Unfortunately these treatments are inadequately applied. This is due to the non-penetration of the principles of physical medicine into general practice. Such methods of treatment are in fact ideal for the general practitioner. The specialist neurologist has no time and is not in sufficient contact with the patient, to apply these treatments himself, although in a better organization of the specialties, organization for treatment, and not only for diagnosis, should be included. Non-medical electrotherapists may help, but the procedure is too delicate, and demands physiopathological and physiological knowledge which only a physician can possess. Thus, even if non-medical electrotherapists are employed for such cases, supervision on the part of the physician is absolutely necessary. It is my impression that when the general practitioner, who has the patient to himself and can follow and treat him for a long time, himself applies the procedures of electrotherapy in paralytic conditions of the muscles, the damage resulting from imperfect treatment of such conditions can be avoided.

Galvanization and faradization exert a strong therapeutic action in the following conditions: (a) various neuritic states with muscular paralysis, (b) conditions of muscular paralysis or paresis resulting from trauma of the nerves, (c) various muscular paralysis and atrophy resulting from reflex conditions such as joint lesions and trauma of the bones and joints.

The principle of treatment of these conditions is stimulation of the metabolic processes of the muscles. When movement occurs, a series of metabolic processes takes place in the muscles following contraction, and maintains the organ in a state of health. The muscles contract normally on account of the stimulus provided by the motor nerves, but when the normal stimulus cannot take place and movement is impossible these metabolic processes cannot occur. There occurs a disturbance of local muscular metabolism and progressive aggravation of the condition. Through galvanization and faradization we stimulate the muscles to contract, replacing the normal stimulus provided by the motor nerves by the artificial stimulus of the electric current. The muscles contract, the metabolic processes which follow contraction are initiated, the nutrition of the muscles becomes more or less normal, and thus cure results.

In order to understand the application of electrical methods in the restoration of the functions of muscles and nerves the basic physiological conceptions of stimulus and irritability must be considered. One of the medical systems so fashionable in the 18th century was that of John Brown of Edinburgh; this was based on the conception of stimulus and was an application of the physiological researches of Haller. Although this system has gone the way of all systems of medicine something of it has remained, and that something is the conception of stimulus and irritability. Life, according to John Brown, could be explained by the action of external stimuli. The tissues, and thus the muscular and nervous tissues, possessed the property of irritability, which is the property of response to external stimuli. The normal functions of life are maintained and promoted by these stimuli, and when the functions lag we can, through artificial stimuli, bring them back to normal or nearly to normal.

In various diseases of the nervous system and of the muscles themselves, normal muscular function is disturbed. By applying a suitable stimulus we can again provoke normal function up to a certain point.

This principle shows the place of electrical therapy in the treatment of nervous and muscular conditions. Electrotherapy cannot be the only treatment, for the electric stimulus is not the only stimulus applicable to nerves and muscles. Movement is a more natural stimulus and thus a more natural procedure, and movement, therefore, must always be combined when possible. This is not always possible, however, as there are diseased muscles which cannot contract spontaneously. Further, as normal function of muscles is a question of normal muscular metabolism we have to consider other metabolic procedures, other methods that stimulate and regulate body metabolism, and these methods may belong to physical medicine, to drugs or to diet.

INVESTIGATION OF NEURO-MUSCULAR FUNCTION BY ELECTRICAL METHODS

When the physician has to treat a patient with defective muscular function, either primary or secondary to a morbid condition of the motor nerves, he completes the diagnosis by determining the form and degree of the muscular impotence.

This can be done by various methods, e.g., by general clinical examination, by bio-chemical methods indicating the condition of muscular metabolism (particularly determination of creatin and creatinine metabolism) and by clinical assessment of the possibility of contraction of the muscles and of the normal movements of the patient.

However, one of the most precise procedures of this exploration is electrical investigation of the function of muscles and of their motor nerves. This investigation, it must be remembered, is only part of the evidence, and must always be interpreted in the light of the totality of symptoms and the whole clinical picture, particularly in the light of the findings regarding metabolic processes, muscular power, reflexes and sensory condition of the affected region. Knowledge of the physiopathology of the central and peripheral nervous system is, therefore, essential for proper interpretation of the findings.

The neurologist is the specialist who can give more definite data on this point. We cannot escape the fact that specialization is necessary, but specialization must be more synthetic. It is strange to remark that very few neurologists themselves perform electrical diagnostic procedures. This investigation they leave to others, a procedure similar to that of a chest specialist who would leave percussion or auscultation to another. This discrepancy is the more apparent because the whole of electrical diagnosis has been a purely neurological work. It began with Duchenne of Boulogne, was developed by Erb and Babinski with the help of the physiological work of Du Bois-Reymond, Pfluger and Remak. With the wider conceptions that today dominate medicine and the medical specialties, and with the introduction of physics into medicine, young neurologists became experts in electrical investigation of neuro-muscular function, and this will greatly benefit patients and general practitioners. In fact the ideal would be for the specialist neurologist to carry out electrical investigations with the general practitioner, and leave subsequent treatment of muscular paralysis by means of galvanic and faradic current to the general practitioner.

PRINCIPLES OF ELECTRICAL TESTING

I have remarked that general practitioners consider electrical testing as a very complicated process. In fact, it is not complicated. Certain fundamental biological principles must first be understood, and with a good galvanic-faradic apparatus and a little practice anyone can achieve success in electrical testing. The method here described is the old method of galvano-faradic testing. Recently it has been superseded by two other procedures, on which a few words will be said, namely, the condenser testing introduced by Lewis Jones and principally the investigation of chronaxia introduced by Lapicque Bourguignon, and his co-workers. These procedures, which are more complicated and not for general practice, are at present interesting from the scientific point of view for their great precision, but from a practical point of view they offer no superiority over the classical method of galvano-faradic testing. It must be remembered that this method is not absolute. It gives only one element of diagnosis. It is a real clinical procedure, and clinical procedures, to be effective, must not be complicated.

Through electrical testing we investigate certain functions of peripheral motor nerves and of muscles, we investigate the excitability and conductivity of the motor nerves, the excitability and contractility of the muscles. These terms need explanation, but first of all it should be realized that the motor nerves are to be considered as a unit beginning at the peripheral neuron in the spinal medulla and terminating in the muscle.

The motor nerve, like all tissues of the body, possesses a special property, knowledge of which was introduced by the great work of Haller and known by the term irritability, which today, for some reason which I cannot guess, has been changed to excitability. This property consists in capacity to respond to external stimuli. The natural stimulus of the motor nerve comes from the central neuron, that is, from the cerebral cortex, and this in its turn is stimulated by various external stimuli.

The normal function of the motor nerve that interests us in this chapter is conductivity, or the property of transmitting impulses. When a motor nerve functions normally as regards conductivity it transmits the impulses received from the cerebral cortex to the muscles that it innervates.

The muscles, like the motor nerves, also posses the property of excitability or irritability, by which they can respond to external stimuli. The normal stimulus of muscles comes from the cerebral cortex and is transmitted to them by the nervous path.

The muscle function that interests us particularly in this chapter is contractility i.e., the property of contracting or shortening of the fibres. This property is generated under the influence of a stimulus.

Electrical investigation of the function of motor nerves and muscles consists in investigation of nervous and muscular excitability, of the conductivity of nerves and of the contractility of muscles. Chief of these, however, is the investigation of excitability. The main object of investigation of the neuro-muscular function is to discover whether nerves and muscles have kept their normal excitability. In other words, do they respond to stimuli normally? For this reason we apply a definite stimulus, the electrical stimulus. In days to come, we may find that some other artificial stimulus, a mechanical percussion stimulus, a thermic stimulus, for example, serves our purpose better, but at present the artificial stimulus provided by the electric current under certain conditions shows us what we want to know, namely, the presence or absence of normal excitability and consequently normality or abnormality of nervous conductivity and muscular contractility.

The galvanic current passing through the muscles stimulates them, but when it flows steadily the stimulation does not lead to contraction. Only when it is suddenly increased in strength (a process known by the rather unhappy term of "closing the current") or when it is decreased suddenly (this is called "opening the current") does contraction occur. The faradic current, being intermittent, leads to muscular contraction.

GENERAL TECHNIQUE OF ELECTRICAL NEURO-MUSCULAR INVESTIGATION: SPECIAL CHARTS

Before proceeding to a study of the clinical applications of low voltage currents (galvanic and faradic) it is important to understand the electrical reactions of muscles and nerves.

There are some special charts which delineate the muscles and nerves of the body. Some of them show points termed points of election of electrical stimulation, the first elaboration of which is due to Duchenne of Boulogne. These points of election are two-fold (a) points of election of muscular stimulation, (b) points of election of nervous stimulation. The points of election of muscular stimulation exist in the region in which the motor nerves penetrate the muscle (about the middle of the cells of the muscle). The points of election of nervous stimulation exist in the region where the motor nerves of muscles are near the surface of the skin.

It is important that the physician who investigates the function of muscles and nerves through electrical methods or attempts to treat nervous and muscular conditions should have such a chart before him. It must be realized, however, that these charts are only diagrammatic, that there are individual variations, and that often the maximum stimulation of muscles and nerves is obtained in regions other than those marked in the diagram. Nevertheless the charts should remain valuable guides.

The first attempt at electric testing should be made on normal muscles and nerves of convenient location and where observation of response is easy. A good example is the biceps. Good lighting is necessary so that the slightest response of muscle can be observed. Patient and operator must be in comfortable positions so as to avoid fatigue. The area to be examined must be warm (a heat lamp can be used for that). Thus the resistance of the skin will be diminished and the exploration painless.

A routine procedure is unipolar testing. Two electrodes are used, the dispersing and the active or exploratory. The former is placed over any part of the body with little muscular tissue or, more simply, held in the hand. Good contact is, of course, absolutely necessary, the electrode must be soaked thoroughly and all precautions indicated for the use of galvanic current should be taken. The active or testing electrode consists in a small metal disc covered by several layers of gauze or asbestos or chamois. It is mounted on a handle with an interrupting device, a make-and-break key. The disc should be 3/4 of an inch in diameter for nerves and small muscles. For larger muscles one can use a larger electrode with 1-1/2 inches of diameter.

Bearing in mind, or having before him, a chart showing the points of election of electrical stimulation, the physician can proceed to the actual testing.

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DEFINITIONS OF TERMS

Precise and clear terms are necessary in science, but unfortunately, in this part of our science, we are hampered by the use of very inconvenient terms. The existence of so many synonyms shows the inadequacy of the terminology. It is necessary therefore, to indicate the significance and synonymity of the terms used.

Interruption of the electric circuit (by releasing the make-or-break key) causes the electro-motive force to fall to zero. This sudden interruption is called opening or breaking the current. The muscular contraction, determined by sudden opening of the current, is called "opening contraction". When the exploring electrode is the positive electrode, or anode, we speak of "anodal opening contraction", when it is the negative, or cathode, we speak of "cathodal opening contraction".

The anodal opening contraction is expressed by A.O.C., the cathodal opening contraction of K.O.C. In my opinion such abbreviations are to be avoided. In scientific work we must be clear, and clarity does not follow from abbreviations which are a sign of laziness of thought.

Sudden establishment of the electric circuit by causing the electro-motive force to rise to its maximum value (by depressing the make-and -break key) is called "closing the circuit" or "making the current". We thus distinguish a closing, or break, muscular contraction, and on lines similar to the above, a cathodal closing or contraction (K.C.C.) and an anodal closing contraction (A.C.C.).Therefore,

Sudden interruption of the galvanic circuit = opening = break.

Sudden establishment of the galvanic current = closing = making.

Muscular contraction due to sudden interruption of the galvanic circuit = closing = contraction = break contraction.

Muscular contraction due to sudden establishment of the electric circuit = opening contraction = make contraction.

INVESTIGATION OF NEURO-MUSCULAR FUNCTION BY THE GALVANIC CURRENT

Investigation of neuro-muscular function by means of the galvanic current (estimation of the irritability and functional power of peripheral motor nerves and muscles) is based on the following facts.

The galvanic current, when flowing steadily, furnishes no stimulus to muscular response. Only when its flow is suddenly started at sufficient strength or is interrupted when flowing at sufficient strength does muscular response occur.

In other words, only at the break (or opening) or at the make (or closing) of the current does contraction occur.

GALVANIC TEST BY CLOSING OR MAKING THE CURRENT

The closing or making with the negative pole (cathodal closing) is described first, as being the most important.
1. The exploring electrode is connected with the negative pole of the galvanic apparatus (the cathode), the dispersing electrode with the positive.
2. The exploring electrode, well moistened, is placed on the motor point.
3. The current is switched on, but as long as the interrupting key is not pressed down, no current flows through the body of the patient and thus to the muscle to be stimulated.
4. The interrupting key is pressed down from time to time, thus "making" the current, that is, allowing it to pass through the body of the patient and thus to the muscle.
In the course of this procedure the following events occur.
1. At first, when the current is not strong, no contraction occurs.
2. When the current is "made" (the making being sudden) and is of sufficient strength, a contraction over the muscle occurs. This contraction is a quick twitch (Cumberbatch).
3. The threshold of excitation is noted. That is, the minimum current which, made suddenly, elicits contraction. Comparison is made with the opposite side. The force and intensity of the contraction is also noted.

This test of "closing" or "making", which has been applied with the negative pole or cathode can be applied to the positive pole or anode. In that case the exploring electrode is connected with the positive pole. This, however, is rarely done in practice.

Cathodal closing, or "making" the current with the negative pole, excites contraction with the least amount of current. This is expressed by

$$KCC > ACC$$

(Kathodal or negative pole closing contractions > anodal or positive pole closing contractions.)

GALVANIC TEST BY OPENING OR BREAKING THE CURRENT

This mode of testing is mentioned for comparison. In practice it is less important.
1. The electrode being in place and the interrupting key being closed, that is, pressed down, the current is switched on. It passes through the body and thus to nerves and muscles.

2. At a certain moment the key is opened. The current is thus interrupted or broken and a contraction occurs in the characteristic form of the galvanic quick twitch.

When the testing electrode is connected with the positive pole and the current is broken, we speak of anodal break or opening (AO). When the testing electrode is connected with the negative pole or cathode we speak of cathodal break or opening (CO).

Normally the contractions elicited by anodal opening require a lesser intensity of current than those elicited by the cathodal opening.

AOC > KOC

The muscular contractions elicited by opening of the current requires a greater intensity of current than those elicited by the closing of the current, the complete polar formula being KCC > AOC > KOC.

TESTING WITH FARADIC CURRENT

1. The dispersing electrode is connected with one pole of the faradic coil -- it makes no difference which.
2. The testing electrode, well moistened, is placed over the point of election of muscular or nervous stimulation.
3. The current is switched on. The secondary coil is advanced slowly so as to increase the intensity of the current, say, at 3/4 of an inch.
4. The key of the interrupting handle is pressed, and thus the current is made and starts to flow through the patient.

The following will happen:
1. If the current is not strong enough only a stinging sensation will be felt under the testing electrode.
2. If the current is strong enough a contraction of the muscles will occur. This contraction will be tetanic, that is, slow and permanent, thus differing from the quick twitch of the galvanic test.
3. The threshold of eliciting this contraction is noted by comparing roughly the length of the advance of the secondary coil. Comparison is made with the muscles on the opposite side.

Compared with the galvanic stimulus the faradic stimulus is very short. The faradic consists in a series of rapid and strong impulses recurring about 100 times per second, each stimulus thus lasting one-hundredth of a second. The stimulus of the galvanic test lasts about 1/2 of a second. For this reason when the nerve supply of a muscle is damaged the short stimulus of the faradic current will bring about no contraction, whether it be applied on the nerve or on the muscle, but the longer and more powerful stimulus of the interrupted galvanic current initiates contraction of the muscle.

INTERPRETATION OF THE RESULTS OF ELECTRICAL TESTING

The following can happen:
1. Nervous and muscular irritability and muscular contractility are normal, and response to the above electrical methods is normal. Stimulation of the nerves at their points of election with the negative galvanic pole elicits a quick twitch,

a brusque single contraction of the muscles innervated by these nerves. Stimulation of these same nerves by the faradic current elicits a tetanic contraction of the muscles they innervate. Stimulation of the muscles at their points of election by the galvanic current causes the same brisk single contraction. Stimulation of the muscles with the faradic current brings about a tetanic contraction.
2. Nervous irritability is increased, and the response to galvanic and faradic current is strong. Contraction follows a lower current strength than normally and the contraction is stronger than that elicited when normal nerves are stimulated.
3. Nervous irritability is decreased or absent. On stimulation of the nerves at their points of election through interrupted galvanic or faradic current the contraction obtained from the muscles innervated by these nerves is less than normal or no response is obtained.
4. Muscular irritability and contractility are accentuated. Stimulation of the muscles at their points of election with the galvanic and faradic currents results in strong contractions, and these are obtained with less current than is normally necessary.
5. Muscle irritability is decreased. Same results as with decrease of nerve irritability on testing muscular points.
6. Muscular irritability and contractility are perverted. The modes of perversion are the longitudinal reaction, the myasthenic reaction and the myotonic reaction.

The longitudinal reaction is characterized by the fact that the most intense contraction of the muscle occurs not when the muscle is stimulated at its point of election (the middle of the belly of the muscle) but at its extremities.

The myotonic reaction, which is found in Thomsen's disease, is characterized by the fact that, on faradic stimulation, the muscles remain in tetanic contraction for a long time, as long as twenty seconds, after stimulation has ceased.

The myasthenic reaction, which is in direct contrast with the myotonic reaction and is found in myasthenia gravis, is characterized by the fact that after initial normal response to faradic current, subsequent stimulation with the same current at the same intensity, elicits less and less response until contractions cease altogether. This reaction indicates an abnormal exhaustion and fatigability of the muscles.

When muscular paralysis is due to a lesion of the superior or cerebral motor neuron peripheral nervous excitability and conductivity and muscular excitability and contractility are normal. The reactions to galvanic and faradic current are normal. This is, of course, not absolute. A lesion of the cerebral neuron may react on the lower motor neuron (the motor nerve and its muscle). At all events divergence from normal as regards electrical reaction is not absolute, although in certain cases there may be an increase in neuro-muscular excitability.

When muscular paralysis is due to a lesion of the inferior motor neuron, the function of this neuron (and of its prolongation, the muscle) is involved, with consequent abnormal reactions to electrical stimulation manifested by decreased excitability and conductivity of the nerve and diminished excitability and contractility of the muscle. The most frequent, but of course not constant, abnormality is known by the term "reaction of degeneration", which indicates a severe lesion of the lower motor neuron.

The incomplete reaction of degeneration (indicated in our slovenly terminology by P.R.D.) consists in (a) weak response to faradic stimulation of the nerve, (b) normal response to galvanic stimulation of the nerve, (c) weak or no response to faradic stimulation of the muscle, (d) weak response (sluggish contraction) to galvanic stimulation of the muscle.

The complete reaction of degeneration (designated as C.R.D.) consists in (a) lack of response of the nerve to faradic and galvanic stimulation, (b) lack of response of the muscle to faradic stimulation, (c) weak response of the muscle to galvanic stimulation, taking the form of sluggish contraction after application of the galvanic stimulus.

When muscular paralysis is due to a primary lesion of the muscle, as in primary amyotrophies, etc., the response to electrical stimulation of nerves is normal, while the response of muscles is normal or indicates diminished excitability. This response, however, does not take the complete form of the reaction of degeneration. This is easily understood if we remember that what we call muscular response to the electric current is really the response of the intramuscular motor innervation of the muscle. In amyotrophies the motor nerve is intact as a rule, thus its excitability and conductivity are normal, and thus response to electrical Stimulation is normal. The muscle is involved, however. Its contractility is diminished, and thus even if the nervous impulses are transmitted normally, the muscle does not respond normally.

Besides its diagnostic significance, investigation of neuro-muscular function by means of the electric current has a prognostic significance, and thus enables the physician to follow up the results of his treatment and the progress of the disease. The symptom-complex of abnormal reactions to electrical stimulation, known as reaction of degeneration, complete or incomplete, occurs after the nerve lesion in about 60 days or more. It develops progressively. Under the influence of treatment it may retrocede. The reappearance of reactions approaching normal indicates to the physician the progress effected by treatment.

CONDENSER METHOD OF TESTING AND CHRONAXIA

The classical method of faradic and galvanic testing has been superseded by more delicate methods. For practical purposes, however, the former method suffices. The disadvantage is that a simple faradic and galvanic test is insufficient for exact measurement of the degree of change in muscular and nervous response. The strength of the ordinary faradic current is not measurable at all, and the faradic response has no great prognostic value because, in a paralysed muscle, voluntary muscle power returns before the response to faradization. The strength of the galvanic current can be measured, but its duration of flow cannot be assessed.

The principle of the condenser set test, which is more delicate, was introduced by Lewis Jones and came into practical use with the Great War. The method determines with great precision the degree of excitability of individual muscles, and is less painful than the ordinary galvanic and faradic tests. But it takes considerably more time than ordinary testing, and often elicits no response at all in the event of a full reaction of degeneration, and thus if used alone would be misleading. On account of this drawback it has not come into extensive use, although it is valuable in institutional work.

The chronaxia test, introduced by Lapique and Bourguignon and others, is a modification of the condenser method. It has enabled important scientific conclusions to be drawn, and is without doubt a most important method for scientific work. For the moment, however, the simple galvanic and faradic tests are sufficient.

A SUGGESTION

Treatment of muscular paralysis due to lesions of the peripheral nerves by the galvanic and faradic currents is extremely important and effective. The basis of this treatment is the electrical testing of the muscles and through this testing the physician can understand the principles of the method he is about to apply. The testing, as I have endeavoured to show in this paper, is not complicated. It demands a good portable galvano-faradic apparatus, a certain knowledge of physiology, and a little practice, beginning with normal muscles. Its use should be more general.

Much could be done to make the method of more general use if special portable apparatus were made with that object, and if with each apparatus, brief directions on the technique of this testing could be added, together with the charts indicating the points of election of nervous and muscular stimulation.

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